A Phased Approach to Evaluating Ballast Water Treatment Systems:
Real-World Testing on Ships

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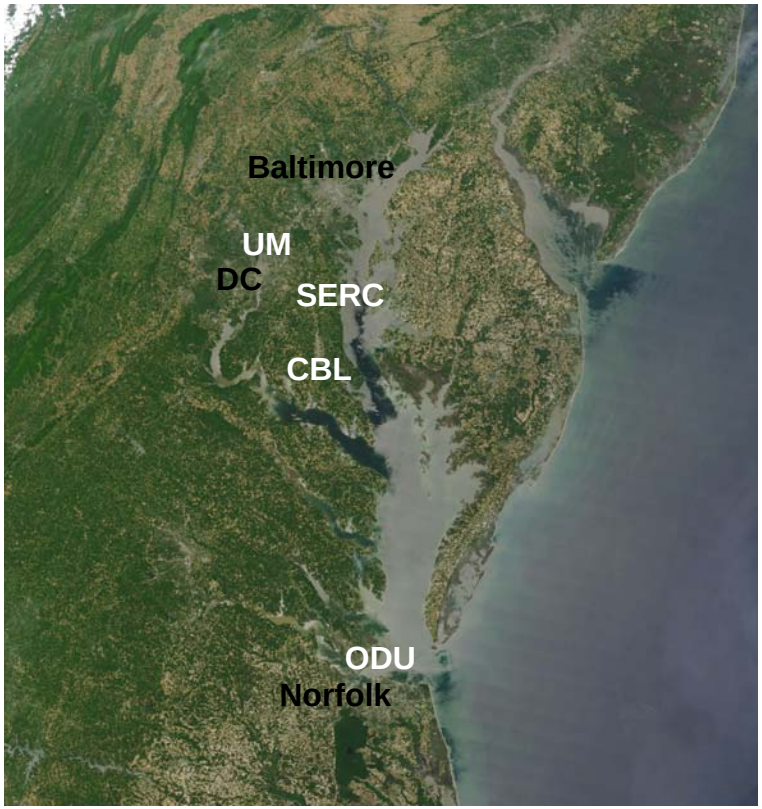
- **Maritime Environmental Resource Center**
- **Dockside/Pilot-scale Shipboard Testing**
- **Active Shipboard Verifications**
- **Conclusions**

Maritime Environmental Resource Center

- **IMO, US, California and other State regulations to prevent invasive species**
- **Developers/vendors need RDTE facilities and expertise**
- **Ship owners and regulators need independent performance testing/verification**
- **Ship owners and regulators need economic assessments and decision tools**

MERC centered on the Chesapeake Bay

- Diverse physical conditions for system testing
- Abundant and taxonomically diverse plankton
- Expertise and experience
- More than 150 known aquatic invasive species in the Bay
- Economically and politically important region



MERC Structure and Function

Foci

- **Mechanical and biological evaluations of ballast water treatment systems – pilot-scale and shipboard**
- **Economic assessments of ballast water regulations and management approaches**
- **Evaluation of other treatments for ship discharges**

Organization

- **Management – CBL/UMCES, MPA, UM, MARAD**
- **Testing Team – CBL/UMCES, SERC, UM**
- **Partners and Advisory Board**

Mechanical and Biological Evaluations

Dockside / Pilot-Scale Testing

- **Goal – Facilitate R&D / scaling up and certification testing (G8, ETV and CSLC)**
- **Approach – Dockside ship and Mobile Platform evaluations**

Active Shipboard Testing

- **Goal – Performance verification and certification testing**
- **Approach – Facilitate STEP applications and NEPA reviews, treatment performance verifications**

Ballast Water Treatment Performance Standards

Organism Size Class	IMO	California
Organisms greater than 50 µm in minimum dimension	< 10 viable organisms / m^3	No detectable living organisms
Organisms 10 – 50 µm in minimum dimension	< 10 viable organisms / ml	< 0.01 living organisms / ml
Organisms less than 10 µm in minimum dimension		< 10^3 bacteria/100 ml < 10^4 viruses/100 ml
Escherichia coli	< 250 cfu/100 ml	< 126 cfu/100 ml
Intestinal *enterococci*	< 100 cfu/100 ml	< 33 cfu/100 ml
Toxicogenic *Vibrio cholerae* (01 & 0139)	< 1 cfu/100 ml or < 1 cfu/gram wet weight zooplankton samples	< 1 cfu/100 ml or < 1 cfu/gram wet weight zoological samples

Mechanical and Biological Evaluations

- **Physical Conditions**

  Temperature, Salinity, Dissolved Oxygen and pH

  Total Suspended Solids and Particulate Organic Carbon

- **Zooplankton (> 50 microns)**

  Pilot-Scale sieve entire volume at 35 µm net, movement and recovery

  Shipboard pump through 35 µm net, movement

- **Phytoplankton (10 - 50 microns)**

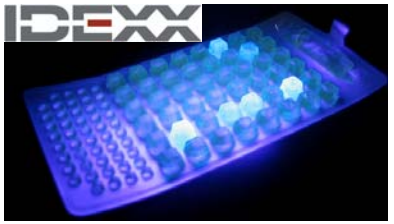
  Chlorophyll + regrowth assays, total cell counts with Lugol's and FDA stains

- **Bacteria (indicator microbes)**

  Total by flow cytometry and culturable by plate counts

  E. coli and *Entercocci* by chromogenic selective substrate most probable number

  V. cholerae by DFA analysis



Dockside Pilot-Scale Evaluations

- **Taking advantage of a MARAD vessel**
  - M/V CAPE WASHINGTON in Port of Baltimore
  - Using ship's ballast system and tanks

- **Control vs. Treated and Before vs. After**
  - In-line sampling, 5-day holding time
  - 5 control and 5 treated 1 m^3 mesocosms

- **Evaluation of MSI Treatment System**
  - Filtration + UV
  - 2 Calibration runs then 5 to 6 trials

- **Lessons Learned**
  - In-line vs. in-tank treatments
  - Trade-offs of working on a vessels

Shipboard Verifications

- **Working with commercial vessel owners**

  M/V PAT CANTRELL, Jacksonville FL to Houston/Port Arthur TX

  Real-world verification of biological and mechanical efficacy

- **Control vs. Treated through time**

  In-tank sampling - before, mid-voyage and after

  2 control and 2 treated ballast tanks

- **Evaluation of NEI VOS System**

  Deoxygenation

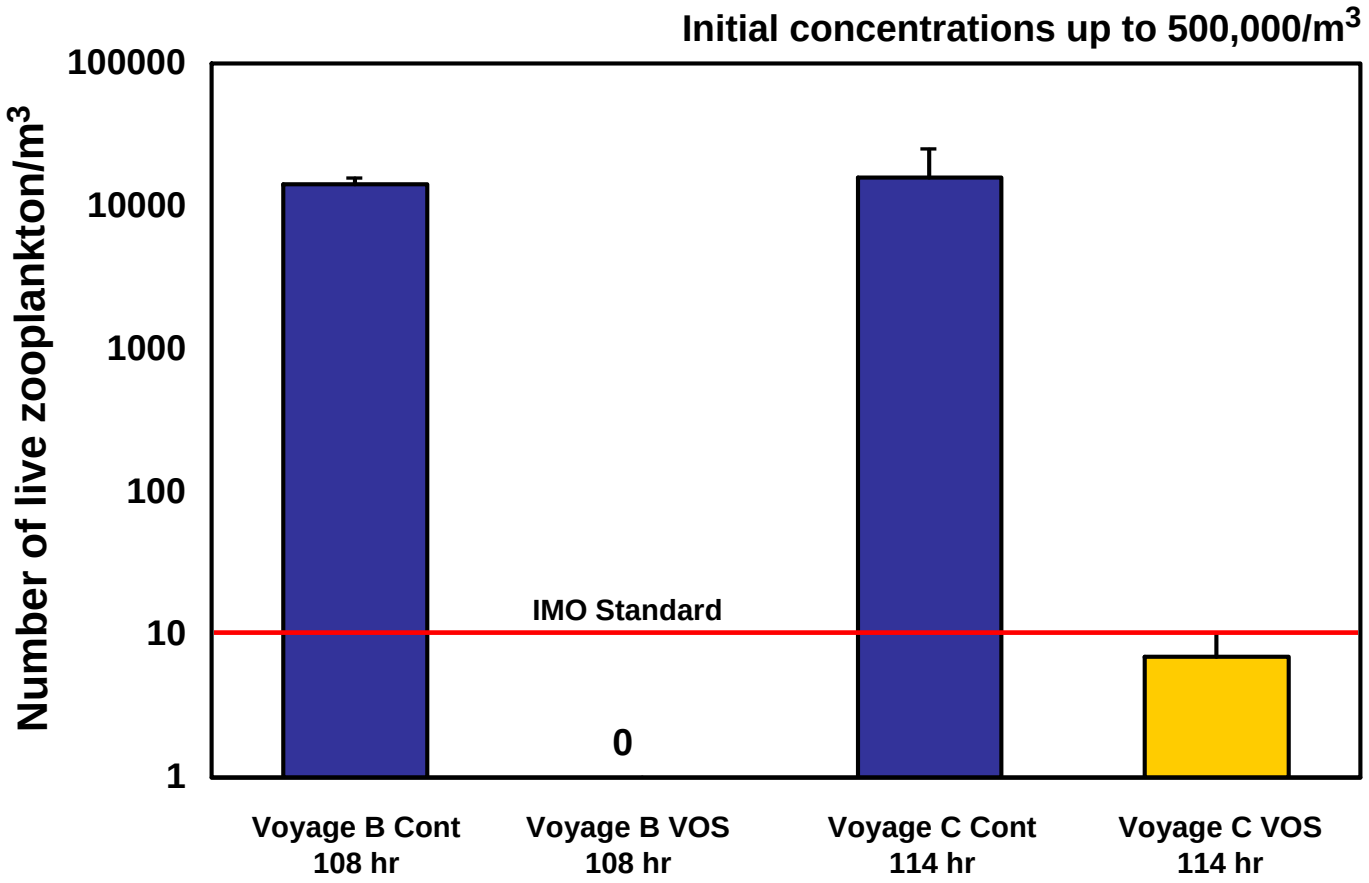
  4 verification voyages over 1.5 years

- **Lessons Learned**

  Consider in-tank recovery/regrowth

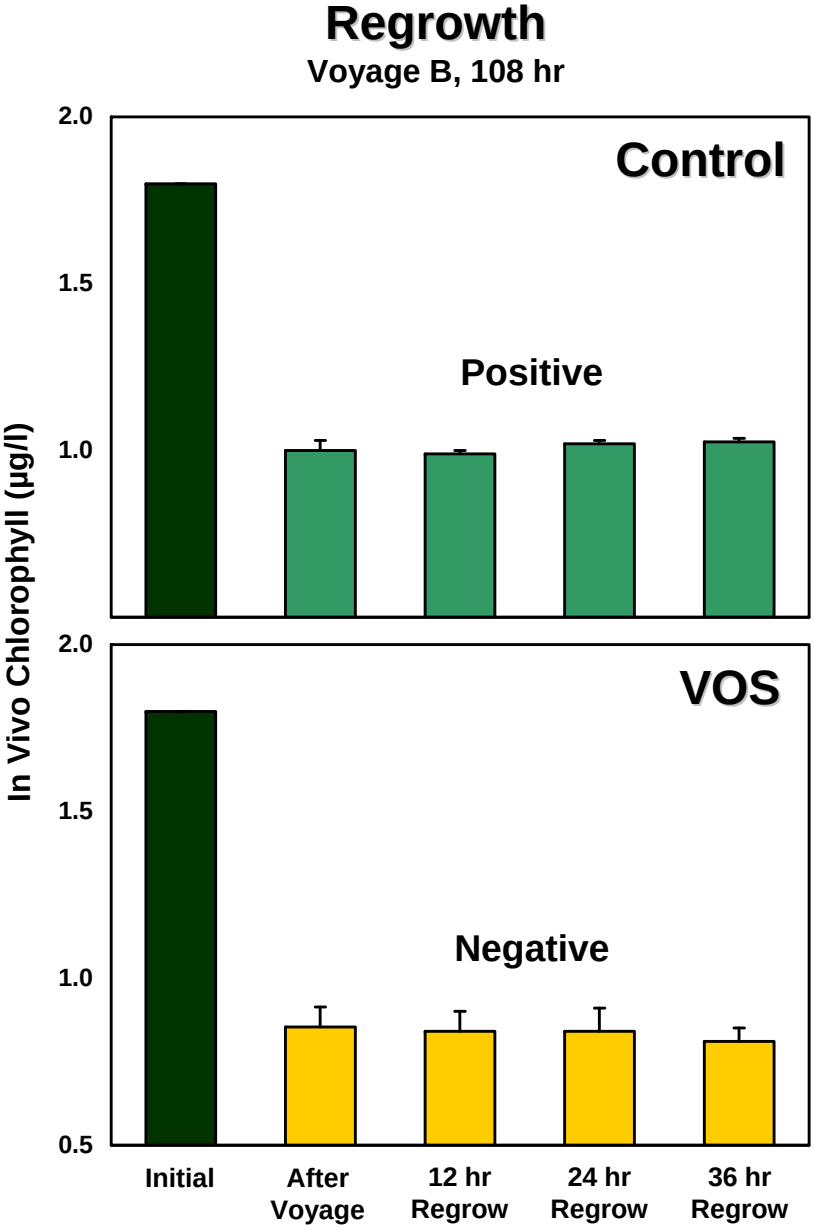
  Difficult/impossible to conduct evaluation as planned - vessel design, unforeseen vessel operational constraints and weather conditions

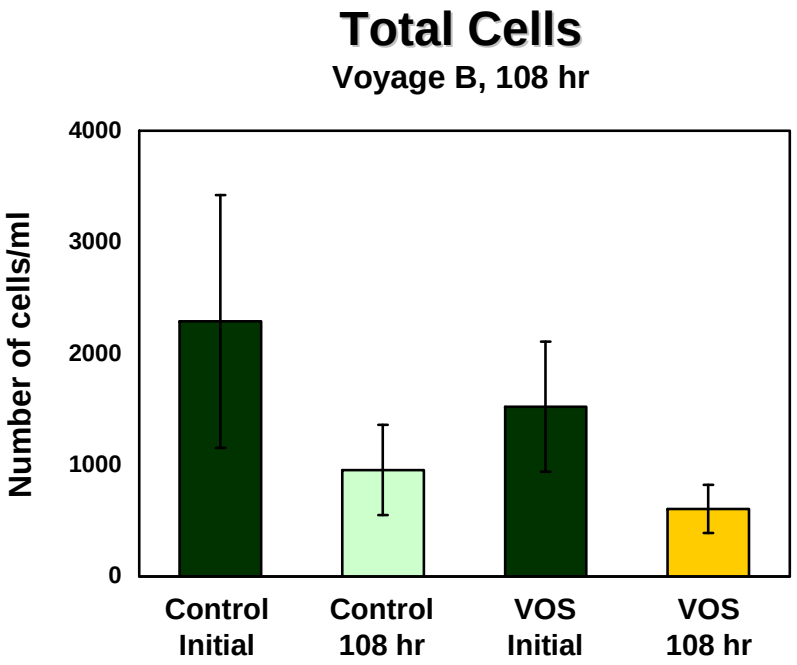
Live Zooplankton (> 50 μm)



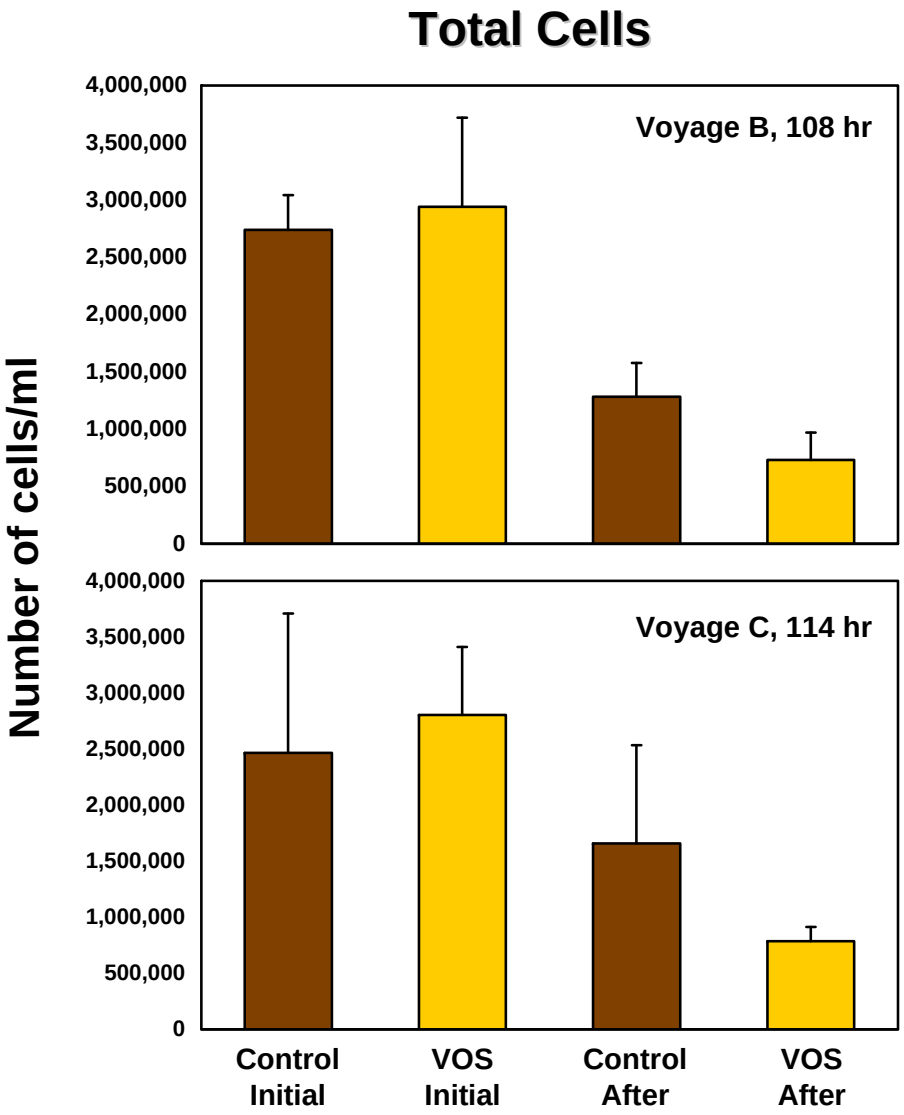
Types: copepods, barnacle larvae, polychaete larvae, isopods, mysids, crustacean nauplii, turbellaria, chaetognaths, gastropods

Live Phytoplankton (10 - 50 μm)





Bacteria and Indicator Microbes



- **Essentially no *E. coli*, *Enteroccoci* or *V. cholerae* found**

Impacts of Discharge

- **Voyage B, 1000 m^3/hr - Port Arthur, TX**

	Receiving 3 m	Ambient	Receiving < 1 m
O_2 (mg/l)	6.4	5.5	6.3
pH	7.6	7.2	7.6

Conclusions

- **Ballast water treatment testing is logistically challenging and expensive**
- **Standardized methods and approaches are needed**
- **Take advantage of real-world testing opportunities and partnerships**
- **There is likely no perfect solution**
- **Ballast water is only one vector**